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(54) **A ROTARY STEERABLE DRILLING ASSEMBLY WITH A ROTATING STEERING DEVICE FOR DRILLING DEVIATED WELLBORES**

ROTIERENDE RICHTBOHRANORDNUNG MIT EINER ROTIERENDEN LENKVORRICHTUNG ZUM BOHREN VERZWEIGTER BOHRLÖCHER

ENSEMBLE DE FORAGE ORIENTABLE ROTATIF DOTÉ D'UN DISPOSITIF D'ORIENTATION ROTATIF DESTINÉ AU FORAGE DE PUITS DÉVIÉS

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Description

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Application No. 15/210669, filed on July 14, 2016.

BACKGROUND

1. Field of the Disclosure

[0002] The disclosure relates generally to rotary drilling systems for drilling of deviated wellbores and particularly to a drilling assembly that utilizes a rotating steering device for drilling deviated wellbores.

2. Background Art

[0003] Wells or wellbores are formed for the production of hydrocarbons (oil and gas) from subsurface formation zones where such hydrocarbons are trapped. To drill a deviated wellbore, a drilling assembly (also referred to as a bottomhole assembly or "BHA") that includes a steering device coupled to the drill bit is used. The steering device tilts a lower portion of the drilling assembly by a selected amount and along a selected direction to form the deviated portions of the wellbore. Various types of steering devices have been proposed and used for drilling deviated wellbores. The drilling assembly also includes a variety of sensors and tools that provide a variety of information relating to the earth formation and drilling parameters.

[0004] In one such steering device, an actuator mechanism is used in which a rotary valve diverts the mud flow towards a piston actuator, while the entire tool body, together with the valve, is rotating inside the wellbore. In such a mechanism, the valve actuation is controlled with respect to the momentary angular position inside the wellbore (up, down, left, right). A control unit maintains a rotary stationary position (also referred to as geostationary) with respect to the wellbore. As an example, if, during drilling, the drill string and thus the drilling assembly rotates at 60 rpm clockwise, the control unit rotates at 60 rpm counterclockwise, driven by, for example, an electric motor. To maintain a rotary stationary position, the control unit may contain navigational devices, such as accelerometer and a magnetometer. In such systems, the actuation force relies on the pressure drop between the pressure inside the tool and the annular pressure outside the tool. This pressure drop is highly dependent on operating parameters and varies over a wide range. The actuation stroke is a reaction based upon the pressure force exerted onto the actuation pistons. Neither force nor stroke is precisely controllable.

[0005] The disclosure herein provides a drilling system that utilizes a steering device that utilizes actuators that rotate along with the drilling assembly to drill deviated wellbores.

[0006] US 3743034 discloses a method and apparatus for directionally drilling a well into the surface of the Earth, including a steering unit with a tilting and actuation device, but does not disclose an actuation device rotating along with the drilling assembly and applying a force in a radial direction on the tilting device.

[0007] US 2012/018225 discloses a drilling assembly utilized for directionally drilling wellbores.

[0008] US 2010/108380 discloses drill bits for drilling subterranean formations, and methods and apparatuses for monitoring operating parameters of drill bits during drilling operations.

SUMMARY

[0009] In one aspect, a drilling assembly for use in drilling of a wellbore is provided, as claimed in claim 1.

[0010] In another aspect, a method of forming a wellbore is provided, as claimed in claim 11.

[0011] Examples of the certain features of an apparatus and methods have been summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features that will be described hereinafter and which will form the subject of the claims.

DRAWINGS

[0012] For a detailed understanding of the apparatus and methods disclosed herein, reference should be made to the accompanying drawings and the detailed description thereof, wherein like elements are generally given same numerals and wherein:

FIG. 1 shows a schematic diagram of an exemplary drilling system that may utilize a steering unit for drilling deviated wellbores, according to one non-limiting embodiment of the disclosure;

FIG. 2 shows an isometric view of certain elements of an elctro-mechanical steering device coupled to a drill bit for drilling deviated wellbores, according to a non-limiting embodiment of the disclosure;

FIG. 3 shows an isometric view of a non-limiting embodiment of an adjuster for use in the steering unit of **FIG. 2;**

FIG. 4 shows certain elements of a modular electromechanical actuator for use in the steering unit of **FIG. 2,** according to a non-limiting embodiment of the disclosure;

FIG. 5 shows an isometric view of components of the steering unit laid out for assembling the steering unit of **FIG. 2;** and

FIG. 6 is a block diagram of a drilling assembly that utilizes a steering device having an actuation de vice and a hydraulic force application device, according to a non-limiting embodiment of the disclosure.

DETAILED DESCRIPTION

[0013] **FIG. 1** is a schematic diagram of an exemplary rotary steerable drilling system **100** that utilizes a steering device (also referred to as steering unit or steering assembly) in a drilling assembly for drilling vertical and deviated wellbores and maintain the steering device geostationary or substantially geostationary while the steering device is rotating. A deviated wellbore is any wellbore that is non-vertical. The drilling system **100** is shown to include a wellbore **110** (also referred to as a "borehole" or "well") being formed in a formation **119** that includes an upper wellbore section **111** with a casing **112** installed therein and a lower wellbore section **114** being drilled with a drill string **120.** The drill string **120** includes a tubular member **116** that carries a drilling assembly **130** (also referred to as the "bottomhole assembly" or "BHA") at its bottom end. The drilling tubular **116** may be a drill pipe made up by joining pipe sections. The drilling assembly **130** is coupled to a disintegrating device **155,** such as a drill bit) or another suitable cutting device, attached to its bottom end. The drilling assembly **130** also includes a number of devices, tools and sensors, as described below. The drilling assembly **130** further includes a steering device **150** to steer a section of the drilling assembly **130** along any desired direction, a methodology often referred to as geosteering. The steering device **150,** in one non-limiting embodiment, includes a tilt device **163** and an actuation device or unit or assembly 160 (for example, an electro-mechanical device or a hydraulic device) that tilts one section, such as the lower section **165** of the drilling assembly **130,** relative to another section, such as the upper section **166** of the drilling assembly **130.** The section **165** is coupled to the drill bit **155.** In general, the actuation device tilts the tilt device **163,** which in turn causes the lower section **165** and thus the drill bit **155** to tilt or point a selected extent along a desired or selected direction, as described in more detail in reference to **FIGS. 2-6.**

[0014] Still referring to **FIG. 1,** the drill string **120** is shown conveyed into the wellbore **110** from an exemplary rig **180** at the surface **167.** The exemplary rig **180** in **FIG. 1** is shown as a land rig for ease of explanation. The apparatus and methods disclosed herein may also be utilized with offshore rigs. A rotary table **169** or a top drive **169a** coupled to the drill pipe **116** may be utilized to rotate the drill string **120** and the drilling assembly **130.** A control unit (also referred to as a "controller" or "surface controller") **190,** which may be a computer-based system, at the surface **167** may be utilized for receiving and processing data transmitted by various sensors and tools (described later) in the drilling assembly **130** and for controlling selected operations of the various devices and sensors in the drilling assembly **130,** including the steering device **150.** The surface controller **190** may include a processor **192,** a data storage device (or a computer-readable medium) **194** for storing data and computer programs **196** accessible to the processor **192** for determining various parameters of interest during drilling of the wellbore **110** and for controlling selected operations of the various tools in the drilling assembly **130** and those of drilling of the wellbore **110.** The data storage device **194** may be any suitable device, including, but not limited to, a read-only memory (ROM), a random-access memory (RAM), a flash memory, a magnetic tape, a hard disc and an optical disk. To drill wellbore **110,** a drilling fluid **179** is pumped under pressure into the tubular member **116,** which fluid passes through the drilling assembly **130** and discharges at the bottom **110a** of the drill bit **155.** The drill bit **155** disintegrates the formation rock into cuttings **151.** The drilling fluid **179** returns to the surface **167** along with the cuttings **151** via annular space **127** (also referred as the "annulus") between the drill string **120** and the wellbore **110.**

[0015] Still referring to **FIG. 1,** the drilling assembly **130** may further include one or more downhole sensors (also referred to as the measurement-while-drilling (MWD) sensors and logging-while-drilling (LWD) sensors or tools, collectively referred to as downhole devices and designated by numeral **175,** and at least one control unit or controller **170** for processing data received from the sensors **175.** The downhole devices **175** may include sensors for providing measurements relating to various drilling parameters, including, but not limited to, vibration, whirl, stick-slip, flow rate, pressure, temperature, and weight-on-bit. The drilling assembly **130** further may include tools, including, but not limited to, a resistivity tool, an acoustic tool, a gamma ray tool, a nuclear tool and a nuclear magnetic resonance tool. Such devices are known in the art and are thus not described herein in detail. The drilling assembly **130** also includes a power generation device **186** and a suitable telemetry unit **188,** which may utilize any suitable telemetry technique, including, but not limited to, mud pulse telemetry, electromagnetic telemetry, acoustic telemetry and wired pipe. Such telemetry techniques are known in the art and are thus not described herein in detail. Drilling assembly **130,** as mentioned above, includes the steering device **150** that enables an operator to steer the drill bit **155** in desired directions to drill deviated wellbores when the drilling assembly is rotating and to maintain the steering device geostationary or substantially geostationary. Stabilizers, such as stabilizers **162** and **164** are provided along the lower section **165** and the upper section **166** to stabilize the steering section **150** and the drill bit **155.** Additional stabilizers may be used to stabilize the drilling assembly **130.** The controller **170** may include a processor **172,** such as a microprocessor, a data storage device **174,** such as a solid state memory, and a program **176** accessible to the processor **172.** The controller **170** communicates with the controller **190** to control various functions and operations of the tools and devices in the drilling assembly. During drilling, the steering unit **150** controls the tilt and direction of the drill bit **155,** as described in more detail in reference to **FIGS. 2-6.**

[0016] **FIG. 2** shows an isometric view of certain elements or components of the steering device **150** for use in a drilling assembly, such as drilling assembly **130** of **FIG. 1,** to steer or tilt the drill bit **155** for drilling deviated wellbores, according to one non-limiting embodiment of the disclosure. The drilling assembly **130** includes a housing or collar **210** for housing the various elements or components of the steering device **150.** The steering device **150** includes a tilt device **163** and an actuation device **160** for tilting the lower section **165** with respect the upper section **166.** In one non-limiting embodiment, the tilt device **163** includes an adjuster **242** and a joint **244.** The upper section **166** and the lower section **165** are coupled by the joint **244.** The adjuster **242** is coupled to the joint **244** in a manner such that when the adjuster **242** is moved a certain amount along a certain direction, it causes the joint **244** to tilt accordingly. The tilt device **163** can be tilted by the actuation device **160** along any direction and by any desired amount to cause the lower section **165** and thus the drill bit **155** to point in any desired direction about a selected point or location in the drilling assembly **130.** The adjuster **242** may be a swivel or another suitable device. The joint **244** may be one of a cardan joint, homokinetic joint, constant velocity joint, universal joint, knuckle joint, Hooke's joint, u-joint or another suitable device. The joint **244** transfers axial and torsional loads between the upper section **166** and the lower section **165,** while maintaining angular flexibility between the two sections. Stabilizers **162** and **164** are disposed at suitable locations around the steering assembly **150,** such as one around the lower section **165** and the other around the upper section **166,** to provide stability to the steering unit **150** and the drill bit 155 during drilling operations. In one non-limiting embodiment, the actuation device **160** further includes a suitable number, such as three or more, of electro-mechanical actuators, such as actuators **222a, 222b** and **222c,** radially arranged spaced apart in the actuation device **160.** Each such actuator is connected to a corresponding end **242a-242c** of the adjuster **242.** In one embodiment, each actuator is a longitudinal device having a lower end that can be extended and retracted to apply a desired force on the adjuster substantially parallel to the axis **230** to cause the adjuster **160** to move about a longitudinal axis **230** of the steering unit **150.** In **FIG. 2,** end **224a-224c** of actuators **222a-222c** are shown directly connected respectively to the ends or abutting elements **242a-242c** of the adjuster **242.** As described in reference to **FIG. 1,** the steering unit **150** is part of the drilling assembly **130.** During drilling, as the drilling assembly 130 rotates, the steering unit **150** and thus each actuator rotates therewith. Each actuator **222a-222c** is configured to apply force on the adjuster **242,** as described later, and depending upon the forces applied, the movement of the adjuster **242** causes the lower section **165** and thus the drill bit **155** to tilt along a desired direction. In the embodiment shown in **FIG. 2,** since the actuators **222a-222c** are mechanically connected to their corresponding adjuster ends **242a-242c,** the forces applied by such actuators and their respective strokes may be synchronized to create any desired steering direction. Although, the actuators **222a-222c** shown apply axial forces on the adjuster **242,** any other suitable device, including, but not limited to a rotary oscillating device, may be utilized to apply forces on the adjuster **242.** In aspects, movement of at least a part the electro-mechanical actuation unit **220** may be selectively adjusted or limited (mechanically, such as by providing a stop in the steering device or electronically by a controller) to cause the lower section **165** to tilt with a selected tilt relative to the upper section **166.** Also, the tilt of the joint **244** may be selectively adjusted or limited to cause the lower section **165** to tilt with a selected tilt relative to the upper section **166.**

[0017] **FIG.** 3 shows an isometric view of non-limiting embodiment of an adjuster **242** for use in the steering unit **150** of **FIG.** 2. Referring to **FIGS. 2** and **3,** the adjuster **242** includes a cylindrical body **342** and a number of spaced apart abutting elements or members, such as connectors **322a, 322b** and **322c,** with connector **322a** having one end **320a** connected to the adjuster end **342a** and the other end **324a** for a direct connection to the actuator **222a,** connector **322b** having one end **320b** connected to the adjuster end **32a** and the other **324b** for direct connection to the actuator **222b** and connector **322c** having one end **320c** connected to an end of **32a** of the adjuster **242** and the other end **324c** for direct connection to the actuator **222c.** The abutting elements may include elements such as a cam, a crank shaft; an eccentric member; a valve; a ramp element; and a lever. In this configuration, when forces are applied onto the adjuster **242** by the actuators, the adjuster **242** may create an eccentric offset in real time in any desired direction by any desired amount about the tool axis **230,** which provides 360 degrees of drill bit maneuvering ability during drilling. The forces on the abutting elements **322a-322c** create a substantially geostationary tilt of the tilt **163** device. In an alternative embodiment, the adjuster **242** may be a hydraulic device that causes the joint **244** to tilt the lower section **165** relative to the upper section **166.,** as described in more detail in reference to **FIG. 6.**

[0018] **FIG. 4** shows certain elements or components of an individual actuator **400** for use as any of the actuators **222a-222c** in the steering unit **150** of **FIG. 2.** In one aspect, the actuator **400** is a unitary device that includes a movable end **420** that may be extended and retracted. The actuator **400** further includes an electric motor **430** that may be rotated in clockwise and anticlockwise directions. The motor **430** drives a gear box **440** (clockwise or anti-clockwise) that in turn rotates a drive screw **450** and thus the end **420** axially in either direction. The actuator **400** further includes a control circuit **460** that controls the operation of the motor **430.** The controller **460** includes electrical circuits **462** and may include a microprocessor **464** and memory device **466** that houses instructions or programs for controlling the operation of the motor **430.** The control circuit **460** is coupled to the motor **430** via conductors through a bus connector **470.** In aspects, the actuator **400** may also include a compression piston device or another suitable device **480** for providing pressure compensation to the actuator **400.** Each such actuator may be a unitary device that is inserted into a protective housing disposed in the actuator unit **150** (**FIG. 1**), as described in reference to **FIG. 5.** During drilling, each such actuator is controlled by its control circuit, which circuit may communicate with the controller **270** (**FIG. 1**) and/or controller **190** (**FIG. 1**) to exert force on the adjuster **242** (**FIG. 2**).

[0019] **FIG. 5** shows an isometric view **500** of components of the steering unit **150** of **FIG. 2** laid out for assembling the steering unit **150.** As described earlier, the actuator unit **150** includes an upper section **166,** a lower section **165,** an adjuster **242** and a joint **244** between the upper section **166** and the lower section **165.** The upper section **166** includes bores or pockets **520a, 520b** and **520c,** corresponding to each of the individual actuators, such as actuators **222a-222c.** The actuator **222a** is inserted into the bore or pocket **520a,** actuator **222b** into bore or pocket **520b** and actuator **222c** into bore or pocket **520c.** The actuators **222a-222c** are connected to the upper end **242a** of the adjuster **242** as described above in reference to **FIGS. 2** and **3.** The adjuster **242** is connected to the lower section **165** by means of the joint **244** to complete the actuator unit assembly. The steering unit **150** is connected to the drill bit **155.**

[0020] **FIG. 6** is a block diagram of a drilling assembly **200** that utilizes a steering device **250** that includes an actuation device **280** and a tilt device **270.** The actuation device **280** shown is the same as shown in **FIG. 2** and includes three or more actuators **280a-280c** disposed in a housing **210.** The tilt device **270** includes an adjuster **277** and a joint **274.** In one non-limiting embodiment, the adjuster **277** includes a separate hydraulic force application device corresponding to each of the actuators **280a-280c.** In **FIG. 6,** force applications devices **277a-277c** respectively correspond to and are connected to actuators **282a-282c.** The actuators **280a-280c** selectively operate their corresponding force application devices **277a-277c** to tilt the lower section **258** relative to the upper section **246** about the joint **274** when the drilling assembly **200** and thus the steering device **250** is rotating. In one non-limiting embodiment, each of the force application devices **277a-277c** includes a valve in fluid communication with pressurized fluid **279** flowing through channel **289** in the drilling assembly **200** and a chamber that houses a piston. In the embodiment of **FIG. 2B**, force application devices **277a-277c** respectively include valves **276a-276c** and pistons **278a-278c** respectively disposed in chambers **281a-281c.** During drilling, the steering device **250** rotates while the pressurized drilling fluid **279** flows through channel **289** and exits through the passages or nozzles **255a** in the drill bit **255.** The exiting fluid **279a** returns to the surface via annulus **291,** which creates a pressure drop between the channel **289** and the annulus **291.** In aspects, the disclosure herein utilizes such a pressure drop to activate the hydraulic force application devices **277a-277c** to create a desired tilt of the lower section **246** relative to the upper section **246** about the joint **274** and to maintain such tilt geostationary or substantially geostationary while the steering assembly **250** is rotating. To tilt the drill bit **255** via the sections **258** and **246,** the actuators **280a-280c** selectively open and close their corresponding valves **276a-276c,** allowing the pressurized fluid **279** from channel **289** to flow to the cylinders **281a-281c** to extend pistons **278a-278c** radially outward, which apply desired forces on the adjuster **277** to tilt the lower section **258** and thus the drill bit **255** along a desired direction. Each piston and cylinder combination may include a gap, such as gap **283a** between piston **278a** and cylinder **281a** and gap **283c** between piston **278c** and chamber **281c.** Such a gap allows the fluid entering a chamber to escape from that chamber into the annulus **291** when the valve is open and the piston is forced back into its cylinder. Alternatively, one or more nozzles or bleed holes (not shown) connected between the cylinder and the annulus **291** may be provided to allow the fluid to flow from the chamber into the annulus **291.** To actively control the tilt of the lower section **258** while the rotary steerable drilling assembly **200** is rotating, the three or more valves **276a-276c** may be activated sequentially and preferably with the same frequency as the rotary speed (frequency) of the drilling assembly **200,** to create a geostationary tilt between the upper section **246** and the lower section **258.** For instance, referring to **FIG. 6,** if an upward drilling direction is desired, the actuator **280c** is momentarily opened, forcing the piston **278c** to extend outward. At the same moment, actuator **280a** would close valve **276a,** blocking pressure from the channel **289** to the piston **278a.** Since all pistons **276a-276c** are mechanically coupled through the joint **274,** piston **278a** would return or retract upon the outboard stroke of piston **278c.** When the drilling assembly **200** rotates, e. g. by 180° and for the case of four actuators distributed equi-spaced around the circumference of the drilling assembly **200,** the activation would reverse, actuator **280a** opening valve **276a** and actuator **280c** closing valve **276c,** thus maintaining a geostationary tilt direction. Similar methods may be utilized to tilt and maintain the tilt geostationary for the embodiment shown in **FIG. 2.**

[0021] Referring to **FIGS. 1-6,** the steering unit **150** described herein is in the lower portion of a drilling assembly **130** (**FIG. 1**) of a rotary drilling system **100.** The steering unit **150** includes an adjuster and a joint connected to an actuation device that maneuvers or tilts the adjuster about a drilling assembly axis, which in turn tilts the joint. The joint tilts a lower section containing the drill bit relative to an upper section of the drilling assembly. The system transmit torque from a collar to the drill bit. In one non-limiting embodiment, the adjuster is actively tilted by a selected number of intermittently activated electro-mechanical actuators. The actuators rotate with the drilling assembly and are controlled by signal inputs from one or more position sensors in the drilling assembly **130.**

Any suitable directional sensors, including, but not limited to magnetometers, accelerometer and gyroscopes may be utilized. Such sensors provide real time position information relating to the wellbore orientation while drilling. Depending on the type and the design of the adjuster the actuators may perform reciprocating or rotary oscillating movement, e. g., actuators coupled to a cam or crank system further enabling the eccentric offset in any desired direction from the drilling assembly axis during each revolution of the drilling assembly, creating a geostationary force and offset of the adjuster axis.

[0022] The system **100** disclosed herein does not require a control unit to counterrotate the tool body rotation. The modular activators positioned in the outer diameter of the actuation assembly receive command signals from a controller located in another section of the tool or higher up in the drilling assembly that may also include navigational sensors. These navigational sensors rotate with the drilling assembly. Such a mechanism can resolve and process the rotary motion of the drilling assembly to calculate momentary angular position (while rotating) and generate commands to the individual actuators substantially instantaneously. As an example, assume the drilling assembly rotates at 1/3 revolutions per second (20 rpm). The current steering vector is intended to point upwards. Assuming the side force element increases eccentricity with positive displacement of the actuation units, the navigational package electronics determine the momentary angular position of the drilling assembly or the steering unit with respect to the earthen formation and sends commands to all of the actuators (stroke and force). At time zero second, one of the actuators (for example the lowermost) receives a command to stroke outward a certain distance. At time 1 second, the steering unit has rotated 120 degrees and the same actuator receives the command to decrease the stroke to approximately to the middle position. At time 1.5 seconds, this actuator is at the uppermost position and the navigational package electronics sends a command to further decrease the stroke of a similar value as sent at zero second, but negative from a middle position. The commands are constantly sent to each actuator with their respective stroke requirements. With the changes for the stroke of the actuators, the angular tilt can be controlled and adjusted in real time. In such a configuration, each actuator performs one stroke per tool revolution (positive and negative from the middle position). To drill a straight wellbore section, all actuators are maintained stationary at their respective middle positions, thus requiring only minimum energy supply to hold the centralized position. The amount of the tilt angle and the momentary direction of the tilt angle controls the drilling direction of the wellbore.

[0023] The foregoing disclosure is directed to the certain exemplary non-limiting embodiments. Various modifications will be apparent to those skilled in the art. It is intended that all such modifications within the scope of the appended claims be embraced by the foregoing disclosure. The words "comprising" and "comprises" as used in the claims are to be interpreted to mean "including but not limited to". Also, the abstract is not to be used to limit the scope of the claims.

Claims

1. A drilling assembly (130; 200) for use in drilling of a wellbore (110), comprising:

    a steering unit (150; 250) having a tilt device (163; 270) and an actuation device (160; 280), wherein a first section and a second section of the drilling assembly (100; 200) are coupled through the tilt device (163; 270),wherein the first section is coupled to a disintegration device (155; 255), and wherein the actuation device (160; 280) rotates along with the drilling assembly (130; 200), and

    wherein the actuation device (160; 280) causes a tilt of the tilt device (163; 270) to cause the first section to tilt relative to the second section along a selected direction while the steering unit is rotating, wherein the actuation device (160; 280) applies forces on the tilt device (163; 270) in a radial direction so as to cause the tilt of the tilt device (163; 270).

2. The drilling assembly of claim 1, wherein the actuation device (160; 280) applies forces on the tilt device (163; 270) in a manner that maintains the tilt of the tilt device (163; 270) geostationary or substantially geostationary when the steering unit is rotating.

3. The drilling assembly of claim 1, wherein the tilt device (163; 270) includes an adjuster (277) and wherein the actuation device (160; 280) applies forces onto the adjuster (277) to cause the tilt of the tilt device (163; 270).

4. The drilling assembly of claim 1, wherein movement of at least a part of the actuation device (160; 280) is selectively adjustable to cause the first section to tilt with a selected tilt relative to the second section.

5. The drilling assembly of claim 3, wherein the tilt device (163; 270) further includes a joint (274) coupled to the actuation device (160; 280), wherein applying the forces on the adjuster (277) by the actuation device (160; 280) causes the first section to tilt about the joint (274) relative to the second section.

6. The drilling assembly of claim 5, wherein a tilt of the joint (274) is selectively adjustable to cause the first section to tilt with a selected tilt relative to the second section.

7. The drilling assembly of claim 1, wherein the tilt de-

vice (163; 270) includes a hydraulic device and wherein the actuation device (160; 280) drives the hydraulic device to cause the tilting of the first section relative to the second section.

8. The drilling assembly of claim 7, wherein the actuation device (160; 280) selectively operates a valve of the hydraulic device to divert fluid flowing through the drilling assembly (130; 200) to cause the tilting of the first section relative to the second section.

9. The drilling assembly of claim 1, further comprising a controller that controls the tilt of the tilt device (163; 270) in response to a parameter of interest.

10. The drilling assembly of claim 9, wherein the parameter of interest is obtained from a response of a sensor selected from a group consisting of: an accelerator; a gyroscope; a magnetometer; a formation evaluation sensor.

11. A method of drilling a wellbore, comprising:

conveying a drilling assembly (130; 200) in the wellbore, wherein the drilling assembly (130; 200) includes a disintegration device (155; 255) at an end thereof, a steering unit that includes a tilt device (163; 270) and an actuation device (160; 280), wherein a first section and a second section of the drilling assembly (130; 200)are coupled through the tilt device (163; 270) and wherein the first section is coupled to a disintegration device (155; 255), wherein the actuation device (160; 280) tilts the tilt device (163; 270) to cause the first section to tilt relative to the second section about the tilt device (163; 270) along a selected direction while the steering unit is rotating, and wherein the actuation device (160; 280) rotates along with the drilling assembly (130; 200);
drilling the wellbore using the disintegration device (155; 255); and
actuating the actuation device (160; 280) to tilt the tilt device (163; 270) to cause the first section to tilt relative to the second section and to maintain the tilt geostationary while the drilling assembly (130; 200) is rotating to form a deviated section of the wellbore, wherein the actuation device (160; 280) applies forces on the tilt device (163; 270) in a radial direction so as to cause the tilt of the tilt device (163; 270).

12. The method of claim 11, wherein the tilt device (163; 270) includes an adjuster (277) and a joint (274) and wherein the method further comprises applying forces on the adjuster (277) to tilt the joint (274) to cause the first section to tilt relative to the second section along the selected direction.

13. The method of claim 11, further comprising selectively adjusting movement of at least a part of the actuation device (160; 280) to cause the first section to tilt with a selected tilt relative to the second section.

14. The method of claim 11, wherein the actuation device (160; 280) includes a plurality of actuators, wherein the method further comprises causing each such actuator to perform one stroke from a middle position thereof per revolution of the drilling assembly (130; 200) to drill the deviated section of the wellbore.

Patentansprüche

1. Bohranordnung (130; 200) zur Verwendung beim Bohren eines Bohrlochs (110), umfassend:

eine Lenkeinheit (150; 250) mit einer Neigungsvorrichtung (163; 270) und einer Betätigungsvorrichtung (160; 280), wobei ein erster Abschnitt und ein zweiter Abschnitt der Bohranordnung (100; 200) durch die Neigungsvorrichtung (163; 270) gekoppelt sind, wobei der erste Abschnitt mit einer Zerfallsvorrichtung (155; 255) gekoppelt ist, und wobei die Betätigungsvorrichtung (160; 280) sich mit der Bohranordnung (130; 200) zusammen dreht, und
wobei die Betätigungsvorrichtung (160; 280) eine Neigung der Neigungsvorrichtung (163; 270) bewirkt, um zu bewirken, dass der erste Abschnitt sich relativ zu dem zweiten Abschnitt entlang einer ausgewählten Richtung neigt, während die Lenkeinheit sich dreht, wobei die Betätigungsvorrichtung (160; 280) in radialer Richtung Kräfte auf die Neigungsvorrichtung (163; 270) ausübt, um die Neigung der Neigungsvorrichtung (163; 270) zu bewirken.

2. Bohranordnung nach Anspruch 1, wobei die Betätigungsvorrichtung (160; 280) Kräfte auf die Neigungsvorrichtung (163; 270) ausübt auf eine Weise, die die Neigung der Neigungsvorrichtung (163; 270) geostationär oder im Wesentlichen geostationär hält, wenn die Lenkeinheit sich dreht.

3. Bohranordnung nach Anspruch 1, wobei die Neigungsvorrichtung (163; 270) einen Einsteller (277) einschließt und wobei die Betätigungsvorrichtung (160; 280) Kräfte auf den Einsteller (277) ausübt, um die Neigung der Neigungsvorrichtung (163; 270) zu bewirken.

4. Bohranordnung nach Anspruch 1, wobei die Bewegung mindestens eines Teils der Betätigungsvorrichtung (160; 280) wahlweise einstellbar ist, um zu bewirken, dass sich der erste Abschnitt mit einer ausgewählten Neigung relativ zu dem zweiten Abschnitt neigt.

5. Bohranordnung nach Anspruch 3, wobei die Neigungsvorrichtung (163; 270) ferner ein Gelenk (274) einschließt, das mit der Betätigungsvorrichtung (160; 280) gekoppelt ist, wobei das Ausüben der Kräfte auf den Einsteller (277) durch die Betätigungsvorrichtung (160; 280) bewirkt, dass sich der erste Abschnitt relativ zu dem zweiten Abschnitt um das Gelenk (274) neigt.

6. Bohranordnung nach Anspruch 5, wobei eine Neigung des Gelenks (274) wahlweise einstellbar ist, um zu bewirken, dass sich der erste Abschnitt mit einer ausgewählten Neigung relativ zu dem zweiten Abschnitt neigt.

7. Bohranordnung nach Anspruch 1, wobei die Neigungsvorrichtung (163; 270) eine Hydraulikvorrichtung einschließt und wobei die Betätigungsvorrichtung (160; 280) die Hydraulikvorrichtung antreibt, um die Neigung des ersten Abschnitts relativ zu dem zweiten Abschnitt zu bewirken.

8. Bohranordnung nach Anspruch 7, wobei die Betätigungsvorrichtung (160; 280) wahlweise ein Ventil der Hydraulikvorrichtung betätigt, um durch die Bohranordnung (130; 200) strömendes Fluid abzuleiten, um die Neigung des ersten Abschnitts relativ zu dem zweiten Abschnitt zu bewirken.

9. Bohranordnung nach Anspruch 1, ferner umfassend eine Steuerung, die die Neigung der Neigungsvorrichtung (163; 270) als Reaktion auf einen interessierenden Parameter steuert.

10. Bohranordnung nach Anspruch 9, wobei der interessierende Parameter aus einer Reaktion eines Sensors erhalten wird, der aus einer Gruppe ausgewählt ist, die aus Folgenden besteht: einem Beschleuniger; einem Gyroskop; einem Magnetometer; einem Formationsbewertungssensor.

11. Verfahren zum Bohren eines Bohrlochs, umfassend:

Transportieren einer Bohranordnung (130; 200) in dem Bohrloch, wobei die Bohranordnung (130; 200) eine Zerfallsvorrichtung (155; 255) an einem Ende davon, eine Lenkeinheit, die eine Neigungsvorrichtung (163; 270) einschließt, und eine Betätigungsvorrichtung (160; 280) einschließt, wobei ein erster Abschnitt und ein zweiter Abschnitt der Bohranordnung (130; 200) durch die Neigungsvorrichtung (163; 270) gekoppelt sind und wobei der erste Abschnitt mit einer Zerfallsvorrichtung (155; 255) gekoppelt ist, wobei die Betätigungsvorrichtung (160; 280) die Neigungsvorrichtung (163; 270) neigt, um zu bewirken, dass der erste Abschnitt sich relativ zu dem zweiten Abschnitt um die Neigungsvorrichtung (163; 270) entlang einer ausgewählten Richtung neigt, während sich die Lenkeinheit dreht, und wobei die Betätigungsvorrichtung (160; 280) sich mit der Bohranordnung (130; 200) zusammen dreht;

Bohren des Bohrlochs unter Verwendung der Zerfallsvorrichtung (255). und

Betätigen der Betätigungsvorrichtung (160; 280), um die Neigungsvorrichtung (163; 270) zu neigen, um zu bewirken, dass der erste Abschnitt sich relativ zu dem zweiten Abschnitt neigt, und um die Neigung geostationär zu halten, während die Bohranordnung (130; 200) sich dreht, um einen verzweigten Abschnitt des Bohrlochs zu bilden, wobei die Betätigungsvorrichtung (160; 280) in radialer Richtung Kräfte auf die Neigungsvorrichtung (163; 270) ausübt, um die Neigung der Neigungsvorrichtung (163; 270) zu bewirken.

12. Verfahren nach Anspruch 11, wobei die Neigungsvorrichtung (163; 270) einen Einsteller (277) und ein Gelenk (274) einschließt und wobei das Verfahren ferner das Ausüben von Kräften auf den Einsteller (277) umfasst, um das Gelenk (274) zu neigen, um zu bewirken, dass sich der erste Abschnitt relativ zu dem zweiten Abschnitt entlang der ausgewählten Richtung neigt.

13. Verfahren nach Anspruch 11, ferner umfassend das wahlweise Einstellen der Bewegung mindestens eines Teils der Betätigungsvorrichtung (160; 280), um zu bewirken, dass sich der erste Abschnitt mit einer ausgewählten Neigung relativ zu dem zweiten Abschnitt neigt.

14. Verfahren nach Anspruch 11, wobei die Betätigungsvorrichtung (160; 280) eine Vielzahl von Betätigungsvorrichtungen einschließt, wobei das Verfahren ferner das Bewirken umfasst, dass jede solche Betätigungsvorrichtung einen Hub von einer mittleren Position davon pro Umdrehung der Bohranordnung (130; 200) zum Bohren des verzweigten Abschnitts des Bohrlochs durchführt.

Revendications

1. Ensemble de forage (130 ; 200) utilisable pour forer un puits de forage (110), comprenant :

une unité d'orientation (150 ; 250) ayant un dispositif d'inclinaison (163 ; 270) et un dispositif d'actionnement (160 ; 280), dans lequel une première section et une seconde section de l'ensemble de forage (100 ; 200) sont couplées à travers le dispositif d'inclinaison (163 ; 270), dans lequel la première section est couplée à un dispositif de désintégration (155 ; 255), et dans lequel le dispositif d'actionnement (160 ; 280) tourne avec l'ensemble de forage (130 ; 200), et

dans lequel le dispositif d'actionnement (160 ; 280) amène une inclinaison du dispositif d'inclinaison (163 ; 270) pour amener la première section à s'incliner par rapport à la seconde section le long d'une direction choisie pendant que l'unité d'orientation tourne, dans lequel le dispositif d'actionnement (160 ; 280) applique des forces sur le dispositif d'inclinaison (163 ; 270) dans une direction radiale de manière à amener l'inclinaison du dispositif d'inclinaison (163 ; 270).

2. Ensemble de forage selon la revendication 1, dans lequel le dispositif d'actionnement (160 ; 280) applique des forces sur le dispositif d'inclinaison (163 ; 270) d'une manière qui maintient l'inclinaison du dispositif d'inclinaison (163 ; 270) géostationnaire ou essentiellement géostationnaire lorsque l'unité d'orientation tourne.

3. Ensemble de forage selon la revendication 1, dans lequel le dispositif d'inclinaison (163 ; 270) inclut un dispositif de réglage (277) et dans lequel le dispositif d'actionnement (160 ; 280) applique des forces sur le dispositif de réglage (277) pour amener l'inclinaison du dispositif d'inclinaison (163 ; 270).

4. Ensemble de forage selon la revendication 1, dans lequel un déplacement d'au moins une partie du dispositif d'actionnement (160 ; 280) est réglable de manière sélective pour amener la première section à s'incliner avec une inclinaison choisie par rapport à la seconde section.

5. Ensemble de forage selon la revendication 3, dans lequel le dispositif d'inclinaison (163 ; 270) inclut en outre une articulation (274) couplée au dispositif d'actionnement (160 ; 280), dans lequel une application des forces sur le dispositif de réglage (277) par le dispositif d'actionnement (160 ; 280) amène la première section à s'incliner autour de l'articulation (274) par rapport à la seconde section.

6. Ensemble de forage selon la revendication 5, dans lequel une inclinaison de l'articulation (274) est réglable de manière sélective pour amener la première section à s'incliner avec une inclinaison choisie par rapport à la seconde section.

7. Ensemble de forage selon la revendication 1, dans lequel le dispositif d'inclinaison (163 ; 270) inclut un dispositif hydraulique et dans lequel le dispositif d'actionnement (160 ; 280) entraîne le dispositif hydraulique pour amener l'inclinaison de la première section par rapport à la seconde section.

8. Ensemble de forage selon la revendication 7, dans lequel le dispositif d'actionnement (160 ; 280) fait fonctionner de manière sélective une vanne du dispositif hydraulique pour détourner un fluide s'écoulant à travers l'ensemble de forage (130 ; 200) pour amener l'inclinaison de la première section par rapport à la seconde section.

9. Ensemble de forage selon la revendication 1, comprenant en outre un dispositif de régulation qui régule l'inclinaison du dispositif d'inclinaison (163 ; 270) en réponse à un paramètre d'intérêt.

10. Ensemble de forage selon la revendication 9, dans lequel le paramètre d'intérêt est obtenu à partir d'une réponse d'un capteur choisi dans un groupe constitué par : un accélérateur ; un gyroscope ; un magnétomètre ; un capteur d'évaluation de formation.

11. Procédé de forage d'un puits de forage, comprenant :

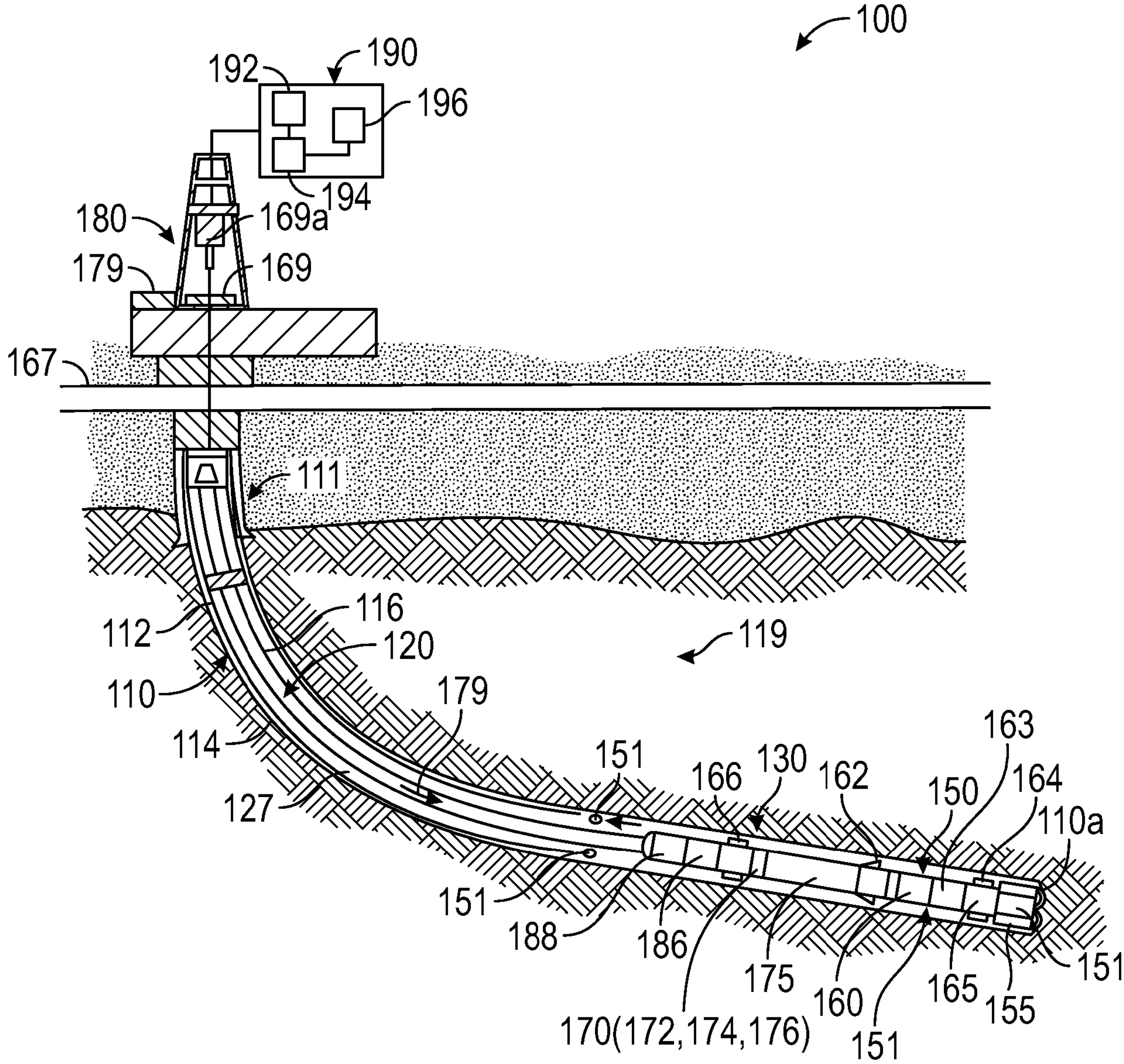
le transport d'un ensemble de forage (130 ; 200) dans le puits de forage, dans lequel l'ensemble de forage (130 ; 200) inclut un dispositif de désintégration (155 ; 255) à une extrémité de celuici, une unité d'orientation qui inclut un dispositif d'inclinaison (163 ; 270) et un dispositif d'actionnement (160 ; 280), dans lequel une première section et une seconde section de l'ensemble de forage (130 ; 200)sont couplées à travers le dispositif d'inclinaison (163 ; 270) et dans lequel la première section est couplée à un dispositif de désintégration (155 ; 255), dans lequel le dispositif d'actionnement (160 ; 280) incline le dispositif d'inclinaison (163 ; 270) pour amener la première section à s'incliner par rapport à la seconde section autour du dispositif d'inclinaison (163 ; 270) le long d'une direction choisie pendant que l'unité d'orientation tourne, et dans lequel le dispositif d'actionnement (160 ; 280) tourne avec l'ensemble de forage (130 ; 200) ;
le forage du puits de forage en utilisant le dispositif de désintégration (155 ; 255) ; et
l'actionnement du dispositif d'actionnement (160 ; 280) pour incliner le dispositif d'inclinaison (163 ; 270) pour amener la première section à s'incliner par rapport à la seconde section et maintenir l'inclinaison géostationnaire pendant que l'ensemble de forage (130 ; 200) tourne pour former une section déviée du puits de forage, dans lequel le dispositif d'actionnement (160 ; 280) applique des forces sur le dispositif

d'inclinaison (163 ; 270) dans une direction radiale de manière à amener l'inclinaison du dispositif d'inclinaison (163 ; 270).

12. Procédé selon la revendication 11, dans lequel le dispositif d'inclinaison (163 ; 270) inclut un dispositif de réglage (277) et une articulation (274) et dans lequel le procédé comprend en outre l'application de forces sur le dispositif de réglage (277) pour incliner l'articulation (274) pour amener la première section à s'incliner par rapport à la seconde section le long de la direction choisie.

13. Procédé selon la revendication 11, comprenant en outre le réglage de manière sélective d'un déplacement d'au moins une partie du dispositif d'actionnement (160 ; 280) pour amener la première section à s'incliner avec une inclinaison choisie par rapport à la seconde section.

14. Procédé selon la revendication 11, dans lequel le dispositif d'actionnement (160 ; 280) inclut une pluralité d'actionneurs, dans lequel le procédé comprend en outre le fait d'amener chacun de ces actionneurs à effectuer une course depuis une position médiane de celui-ci par révolution de l'ensemble de forage (130 ; 200) pour forer la section déviée du puits de forage.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192
196
194
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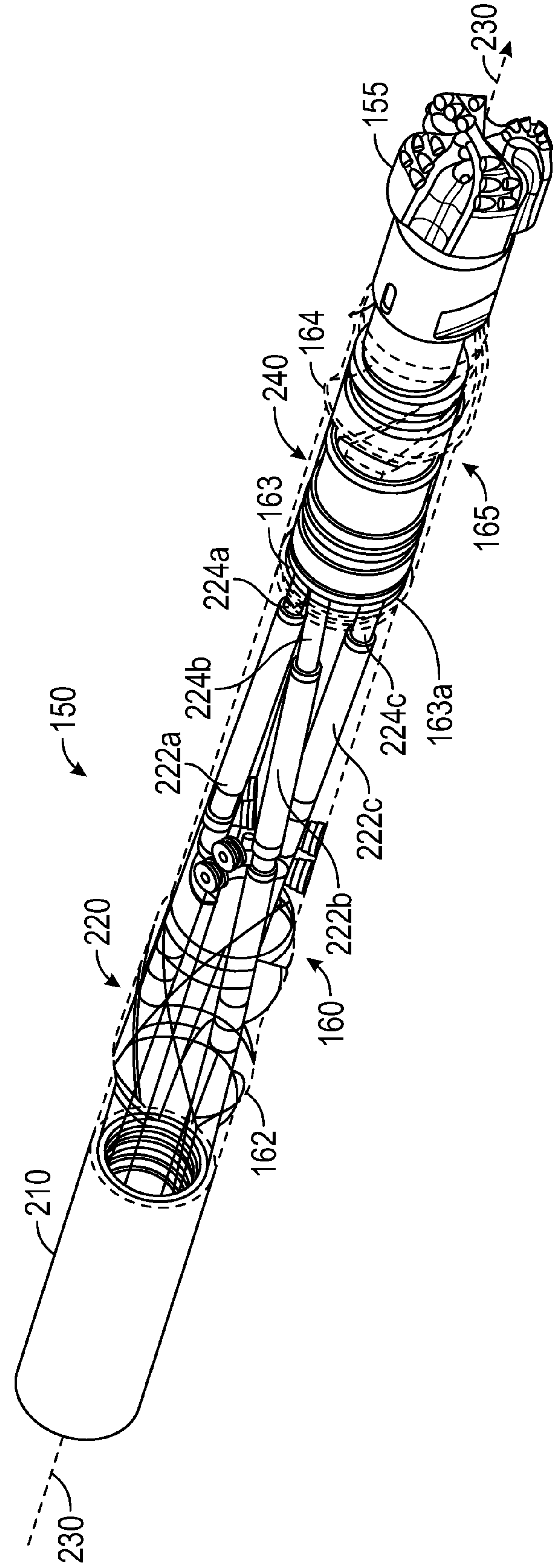
169a
179
169
167
111
112
116
120
119
110
179
114
151
166
130
162
163
150
164
110a
127
151
188
186
175
160
165
155
151
170(172,174,176)
151

FIG. 1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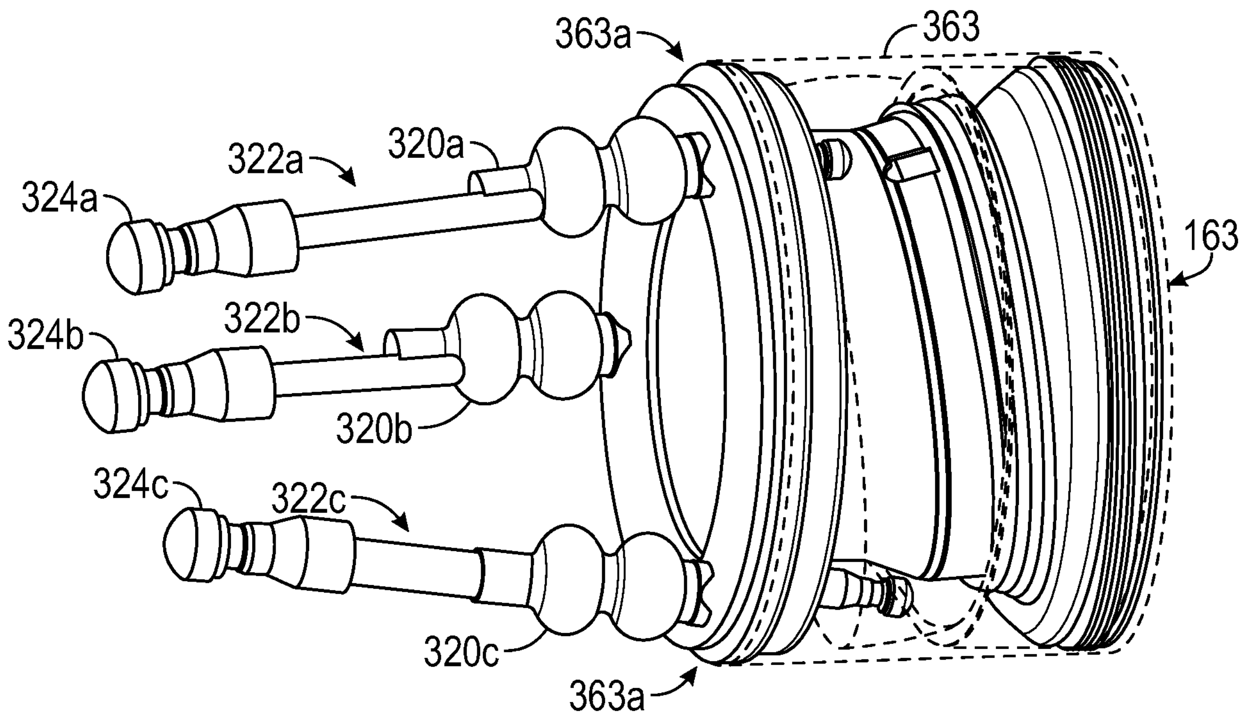
155
164
240
165
163
224a
224b
224c
163a
150
222a
222c
222b
220
160
162
210
230

FIG. 2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363
322a
320a
324a
163
322b
324b
320b
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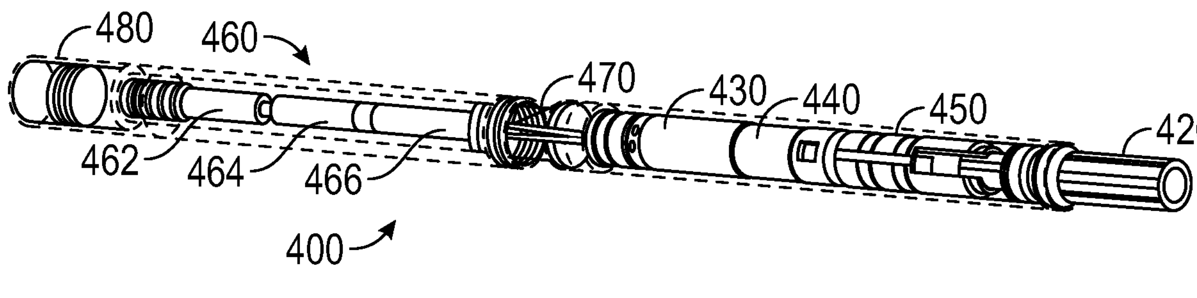
322c
320c
363a

FIG. 3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464
466
400

FIG. 4

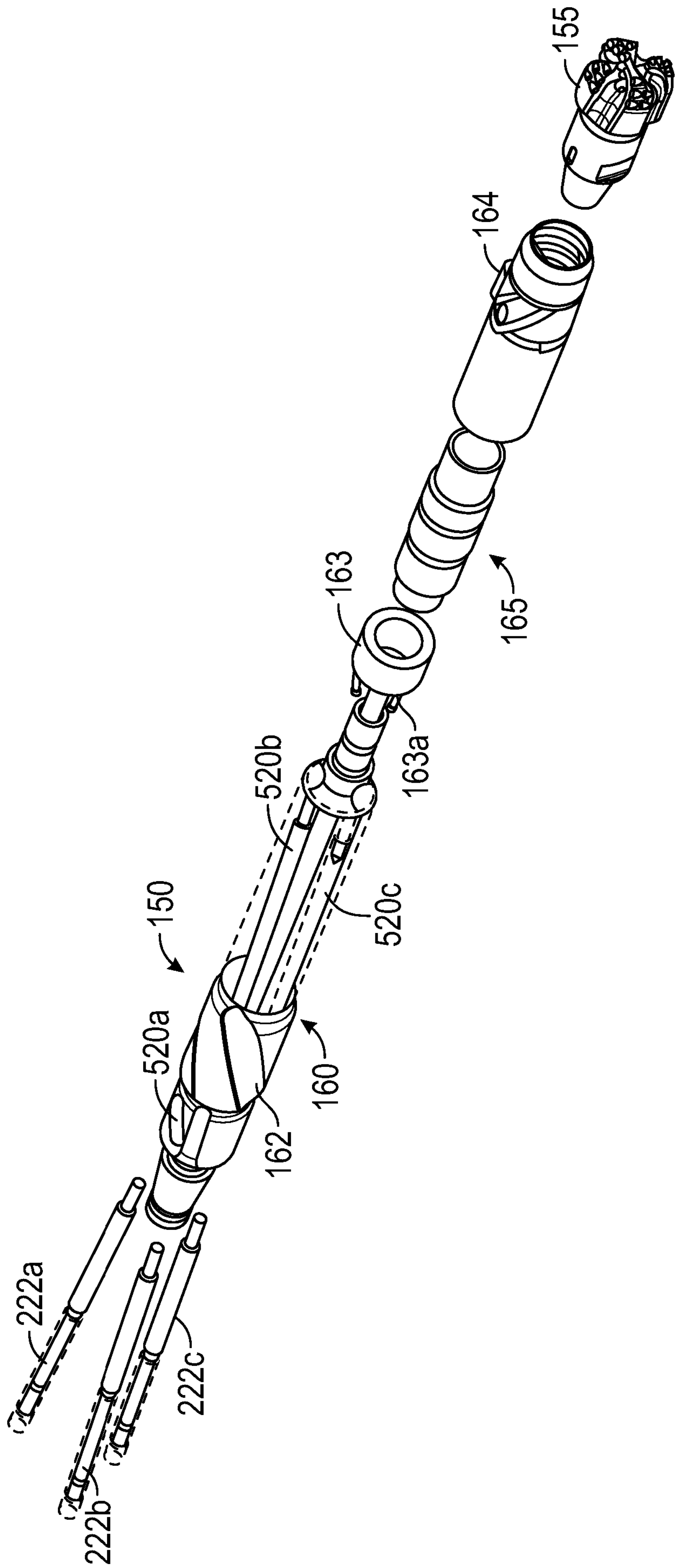
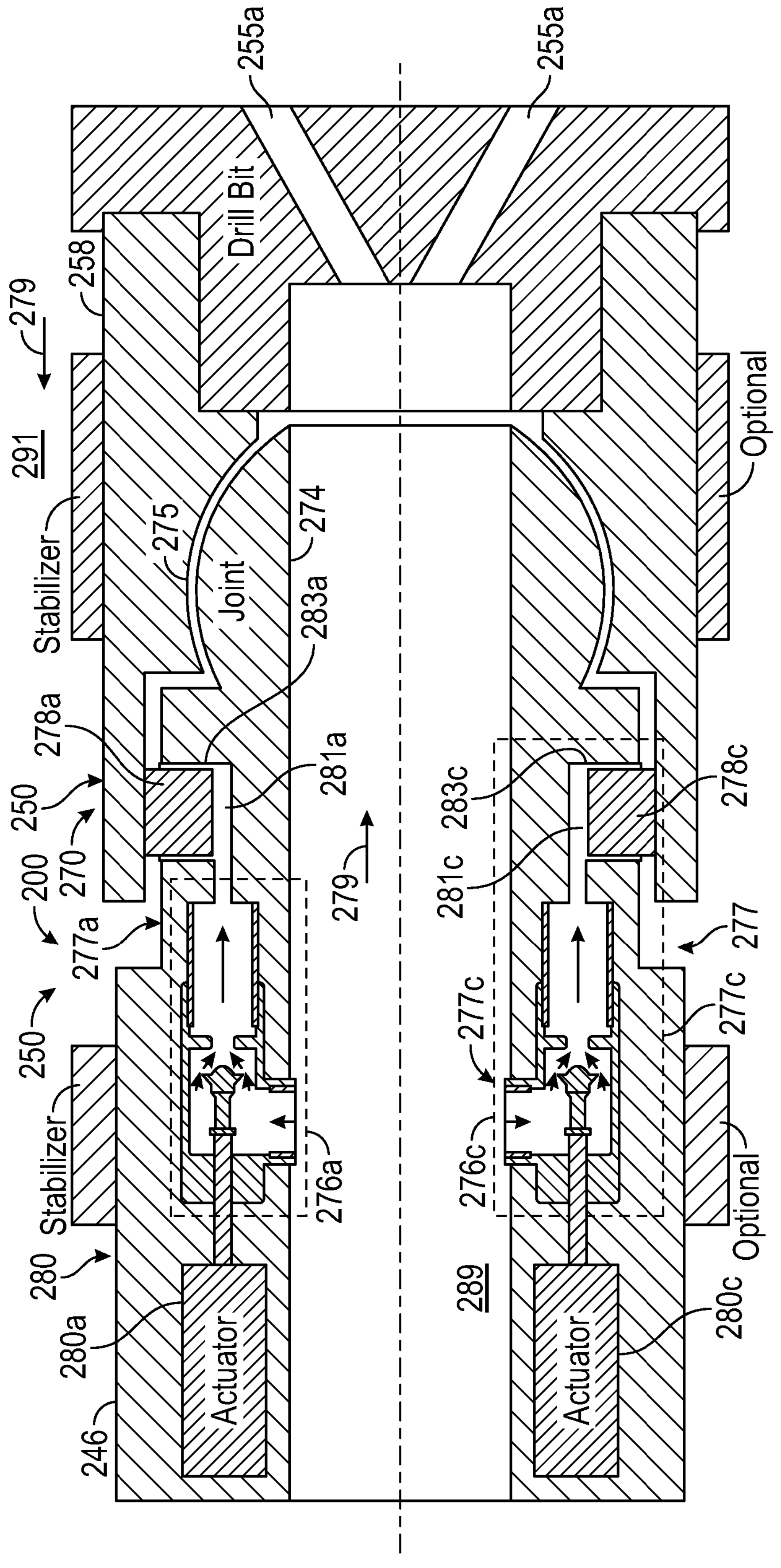


FIG. 5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255a
Drill Bit
258
279
291
Stabilizer
275
Joint
274
283a
278a
250
281a
270
200
279
277a
250
Stabilizer
276a
280
280a
Actuator
246
Optional
Optional
278c
283c
281c
277
277c
277c
276c
289
Actuator
280c

FIG. 6

REFERENCES CITED IN THE DESCRIPTION

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